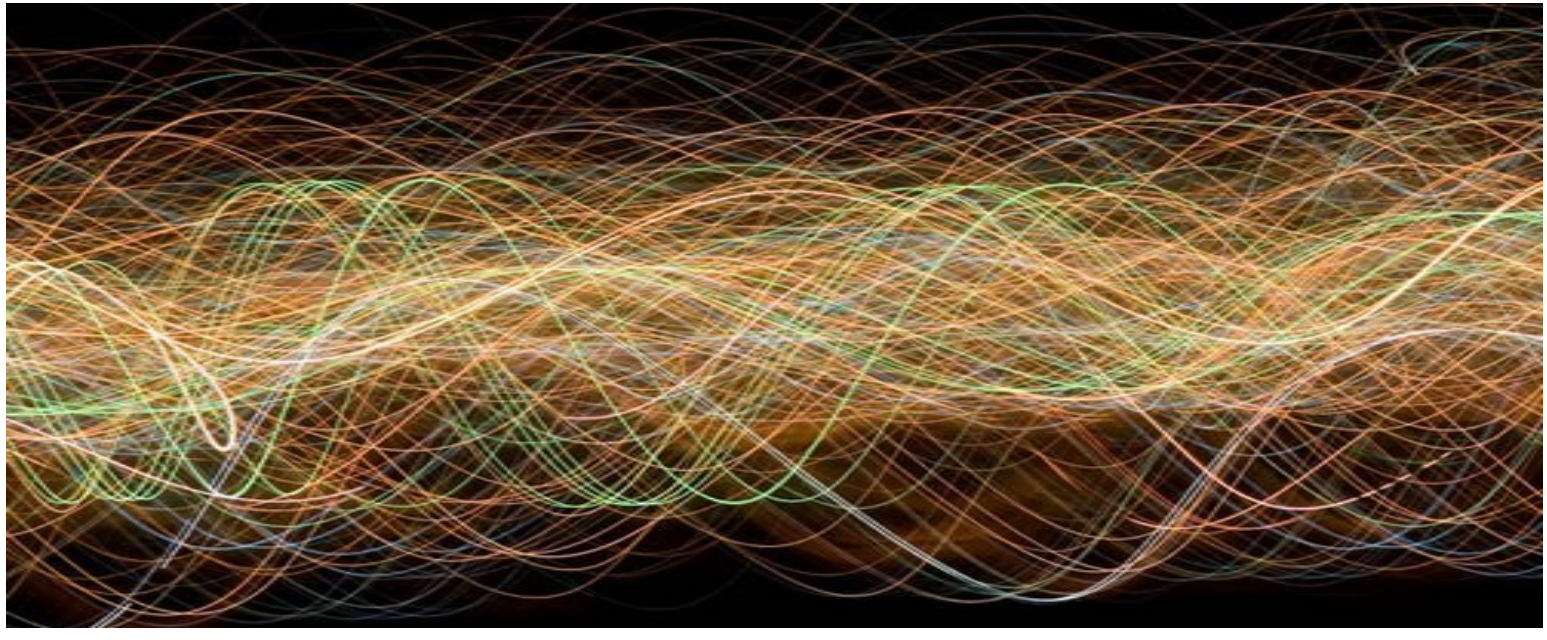
HEARING CONSERVATION PROGRAM

PHYSICS OF SOUND



Learning Objectives

1. **Explain the parameters of sound and how they are measured**
2. **Apply the parameters of sound to the sensitivity of the human ear**
3. **Apply the parameters of speech and sound to an audiogram**
4. **State the intensity levels related to hazardous noise**

What is Sound?

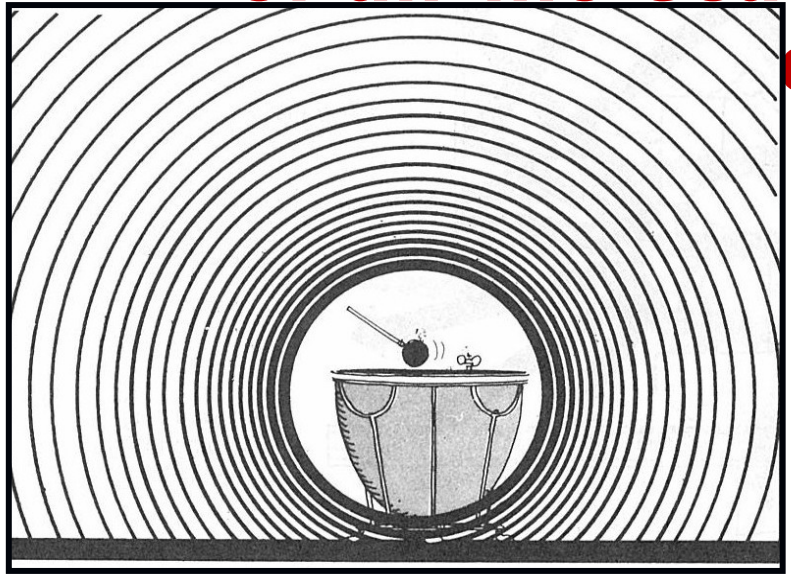
Definition #1 re: Physics

A rapid variation

in atmospheric pressure

caused by some disturbance or agitation

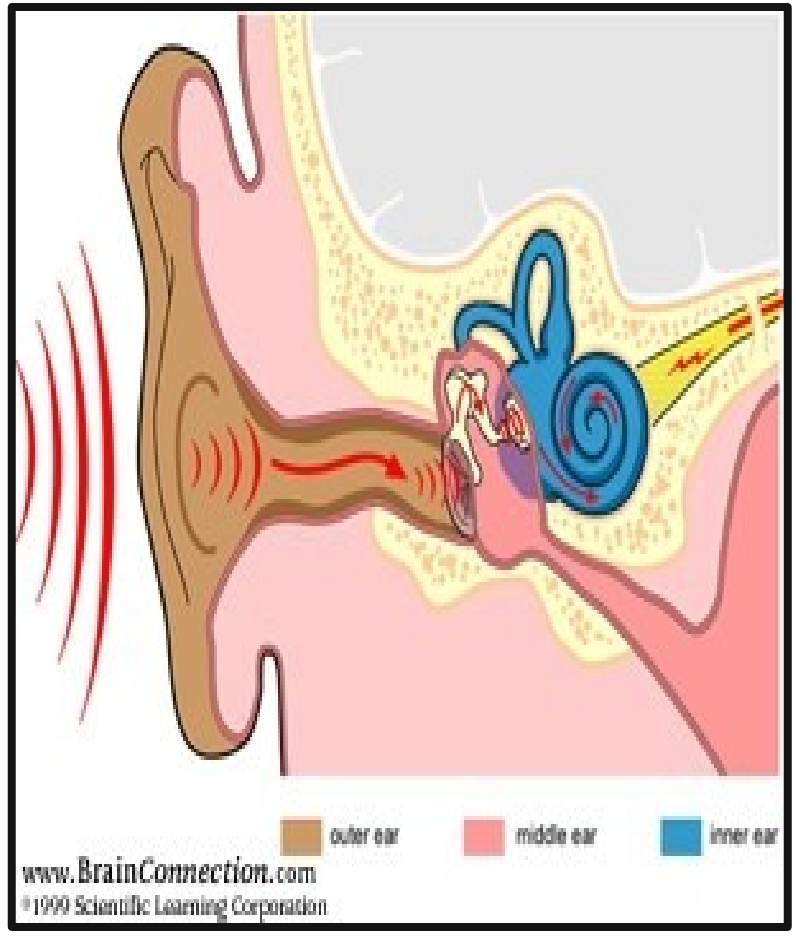
of air molecules or any elastic medium



What is Sound?

Definition #2 re: Human Hearing

The sensation resulting from stimulation of the auditory mechanism by air waves or other vibrations transmitted through the air or other medium.



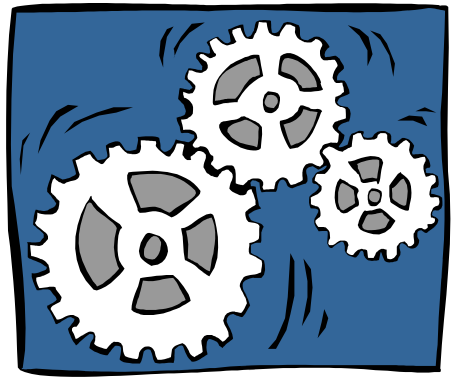
What is Noise?

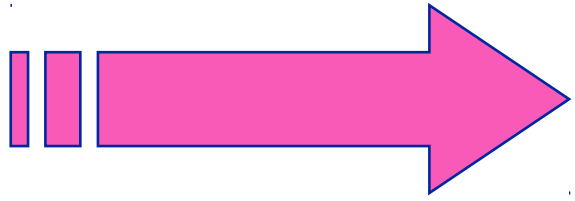
Any *unwanted* sound

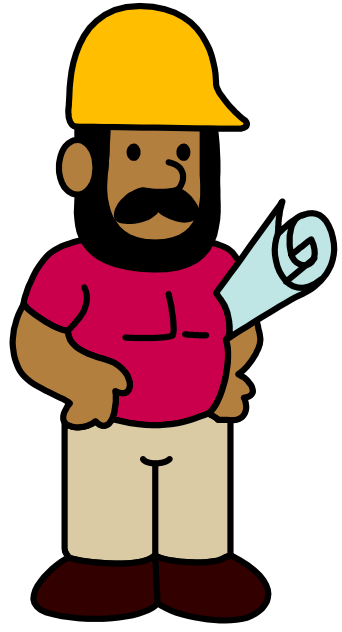
Definition of “noise” varies from person to person

Can be any intensity level but usually louder than conversation level

Required Elements of Sound





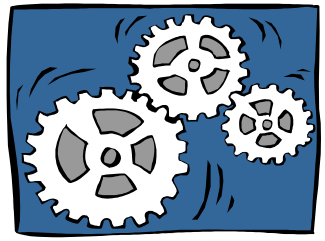


Source of
1. Vibration
2. Energy

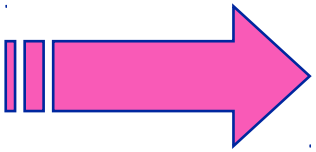
Path or Medium

Receiver

How Sound Waves Are Made



Source of
1. Energy
2. Vibration



Path or Mediu m

Radio

Energy Source ⇨ Electricity
Vibration Source ⇨ Speaker cone ⇨
Path or Medium Air

Submarine

Energy Source ⇨ Fuel
Vibration source ⇨ Propeller
Path or Medium Water

Speech

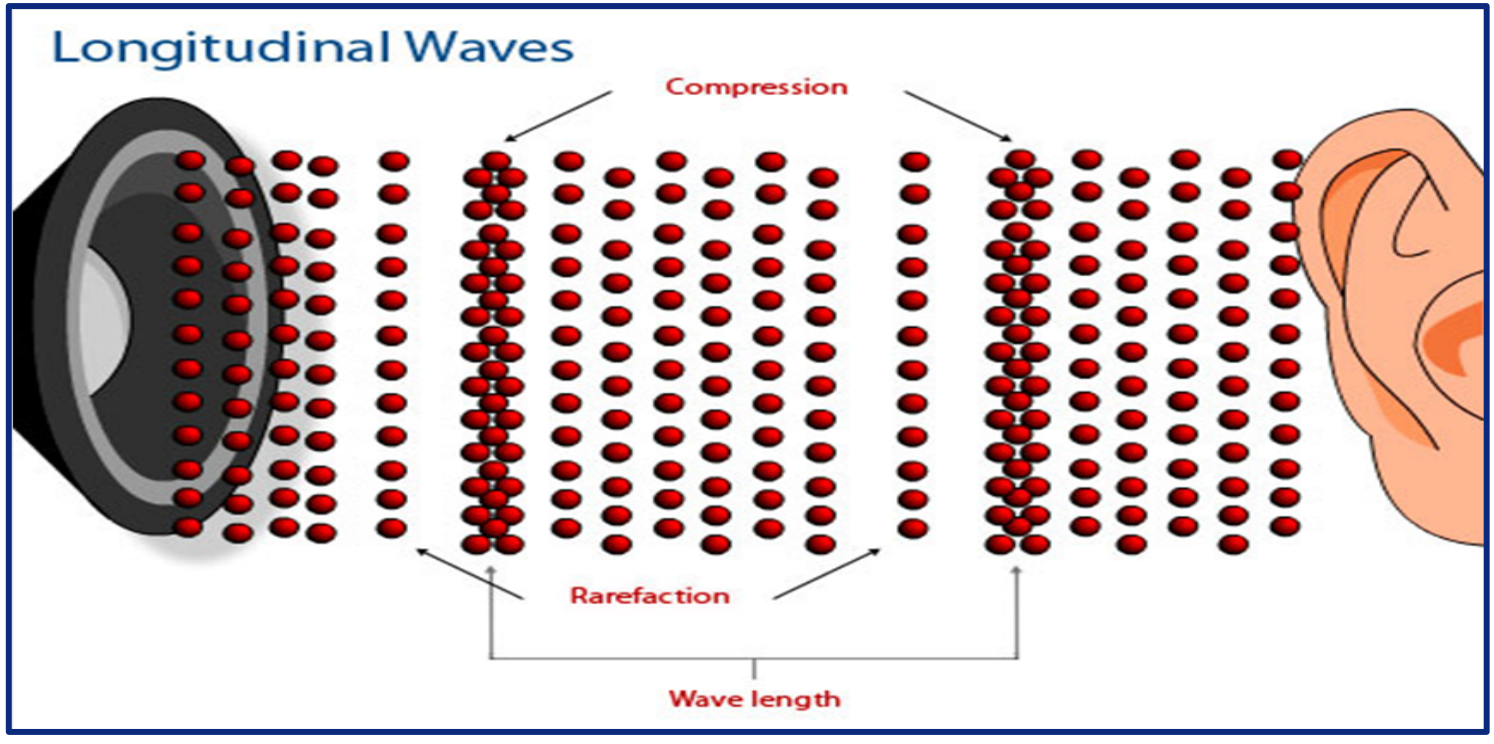
Energy Source ⇨
Lungs/Muscles ⇨
Vibration Source Vocal Cords

Sound Wave Creation

Alternating series of

high pressure or compressions of air molecules and

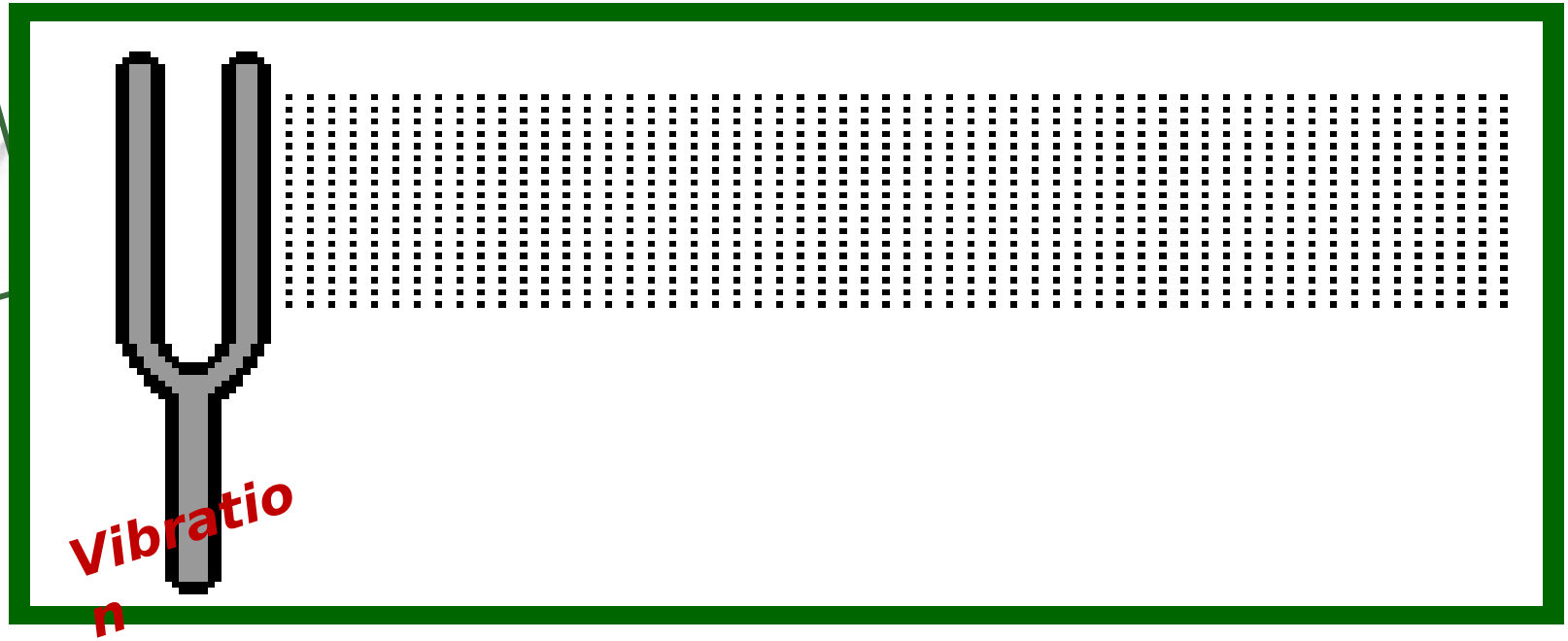
low pressure or rarefactions of air molecules



Sound Wave Animation

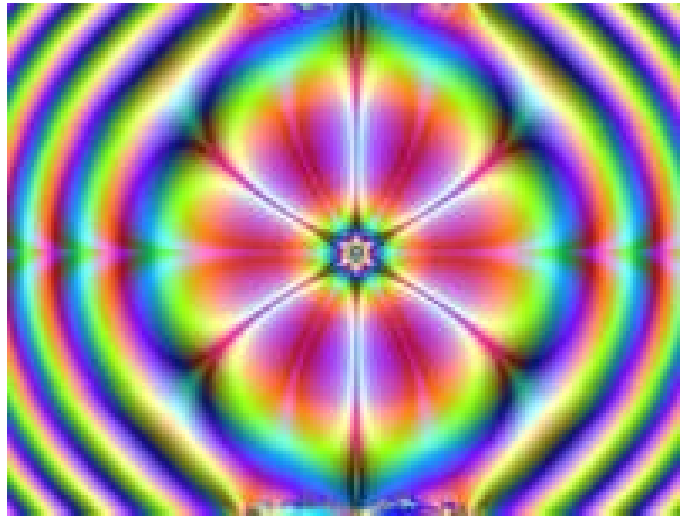
Pure Tone or Sine Wave

Energy Strike Force



Sound Wave Movement

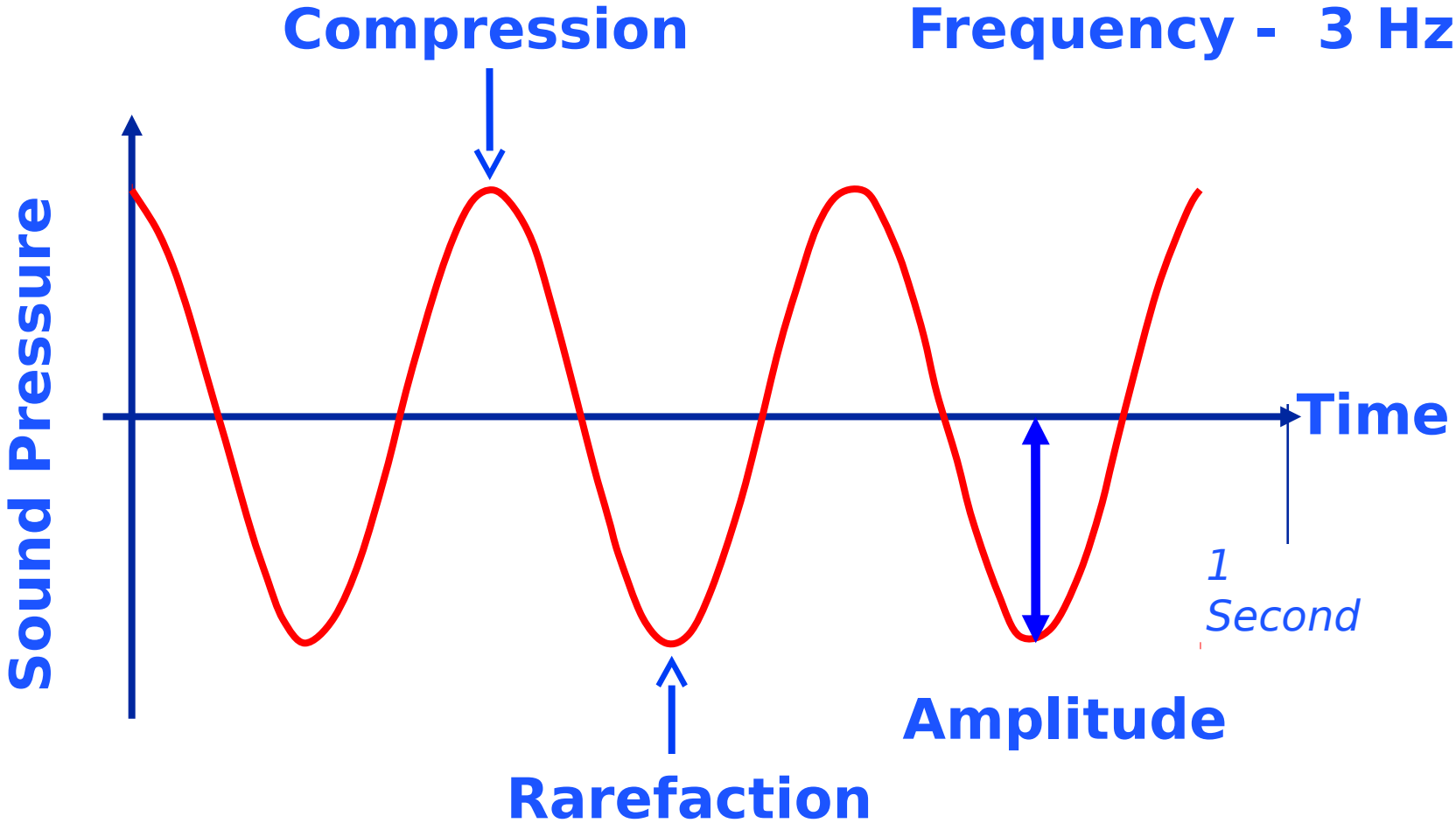
Sound waves move out in ALL directions from a vibrating object



Speed of sound increases with density of the medium

Air	**1,100 ft/sec**	
Water	**4,500 ft/sec**	
Steel	**15,000 ft/sec**	

Basic Sine Wave
Pure Tone



Characteristics/Parameters

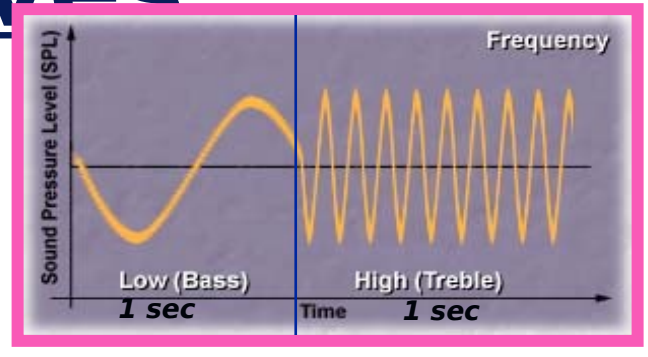
of Sound Waves

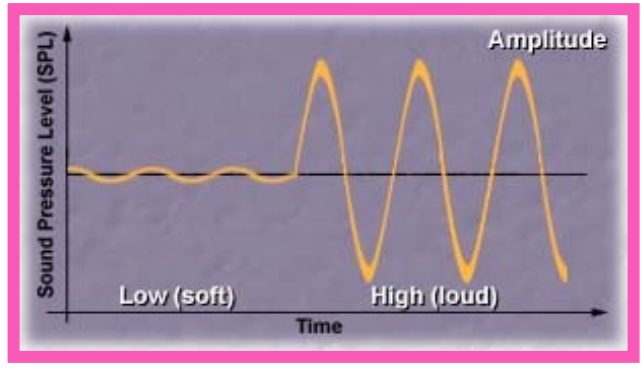
1. **Frequency – Pitch**
   Measured in Hertz - Hz

2. **Intensity – Loudness**
   Measured in decibels - dB

3. **Time -- Duration**
   Measured in seconds or hours (exposure)

4. **Spectrum -- Quality**
   Hz – dB – time combined



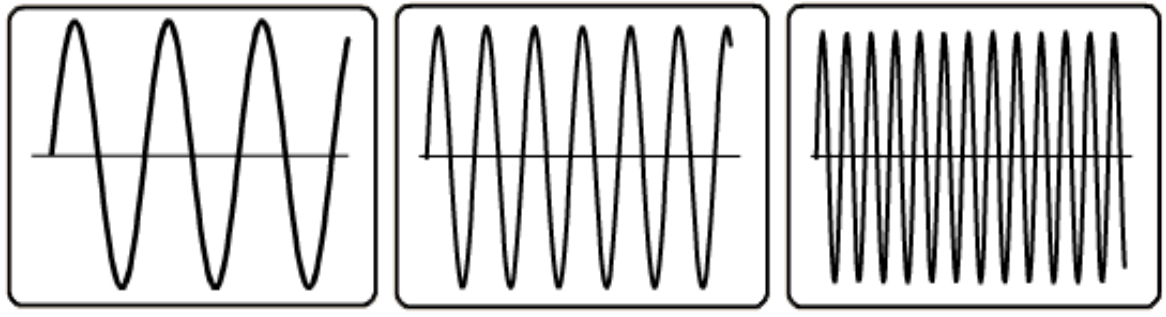


Frequency Facts

- **Frequency is the rate of sound vibration**
- **Measured in cycles per second or Hertz (Hz)**
- **Frequency is perceived as pitch**

Low frequency = bass pitch

High frequency = treble pitch



Low pitch

Low frequency

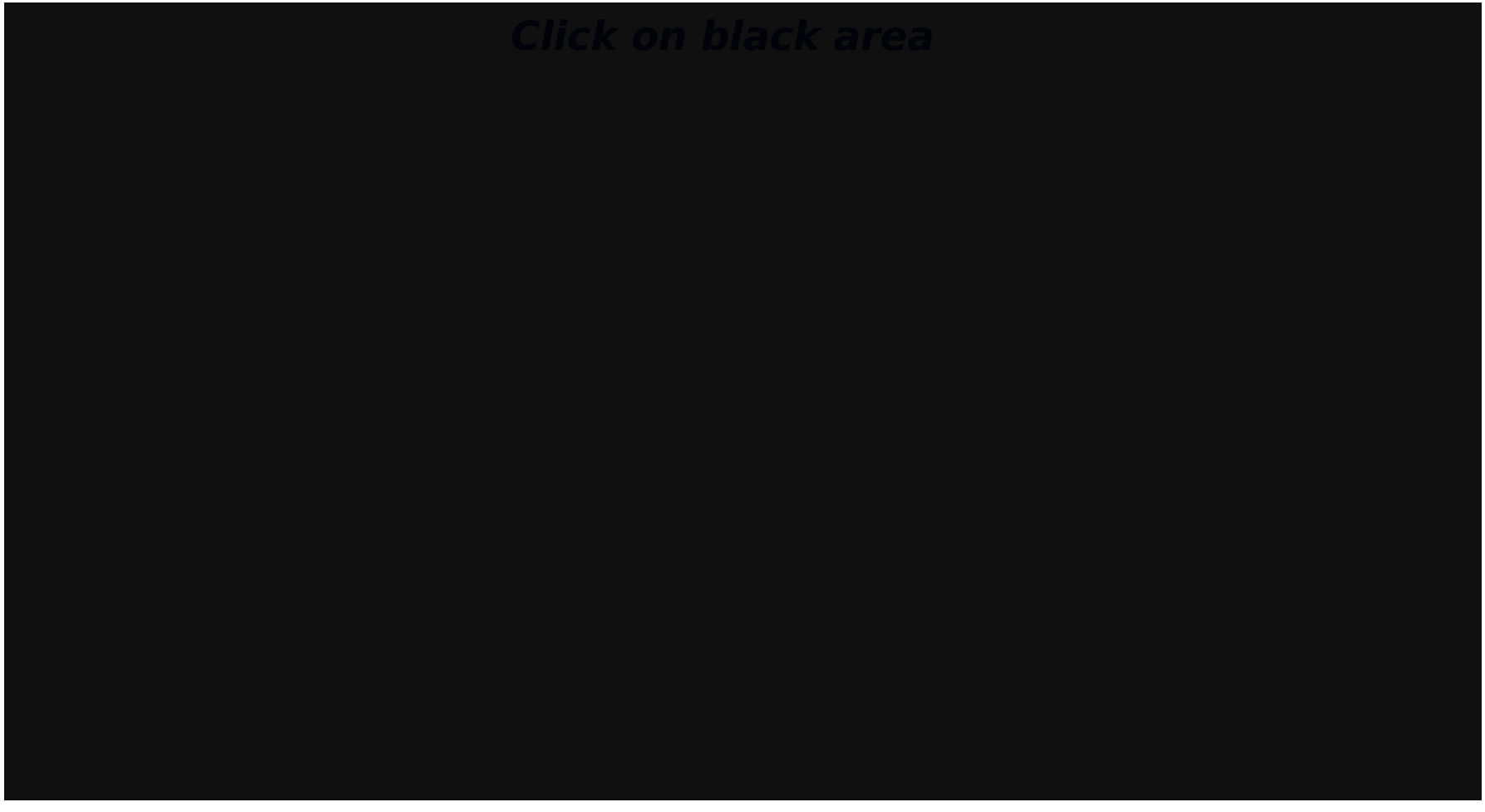
Longer wavelength

High pitch

High frequency

Shorter wavelength

Musical C Note Octave Pure Tone Sine Waves



Human Frequency Range

- Frequency range for humans is 20 - 20,000 Hz
- Most adults hear maximum of 12,000 Hz
- Doubling frequency increases pitch one octave
- Octaves define audiometric test frequencies

  500, 1000, 2000, (3000)*, 4000, (6000)* Hz

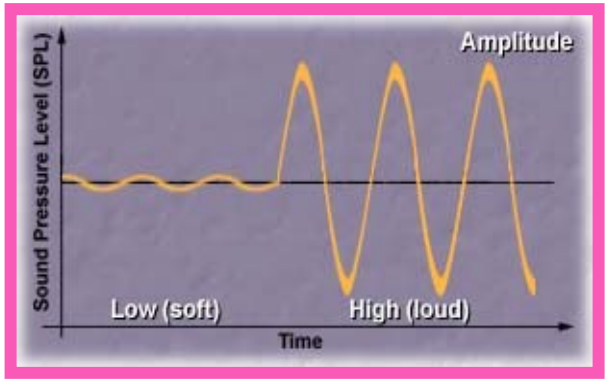
- Critical frequencies to understand speech between 500-4000 Hz

Intensity Facts

- Acoustic power or sound pressure
- In Audiology

Intensity is expressed as the sound pressure level – SPL - , which is a function of distance that the vibrating object is displaced (amplitude), which depends on energy applied.

- Perceived as loudness.
- Measured in decibels (dB)



The Decibel (dB)

A decibel (dB) is a measurement unit related to the logarithm of the ratio of two measures: the quantity being measured and a known reference quantity.

Reference level for Sound Pressure Level (SPL)

20 micropascals (20 µPa), or 0.02 mPa.

This amount of pressure is the smallest pressure that will barely move the eardrum.

Why Logarithms?

To compress the very large range of pressure that
our ears can hear into a small range of numbers for convenience

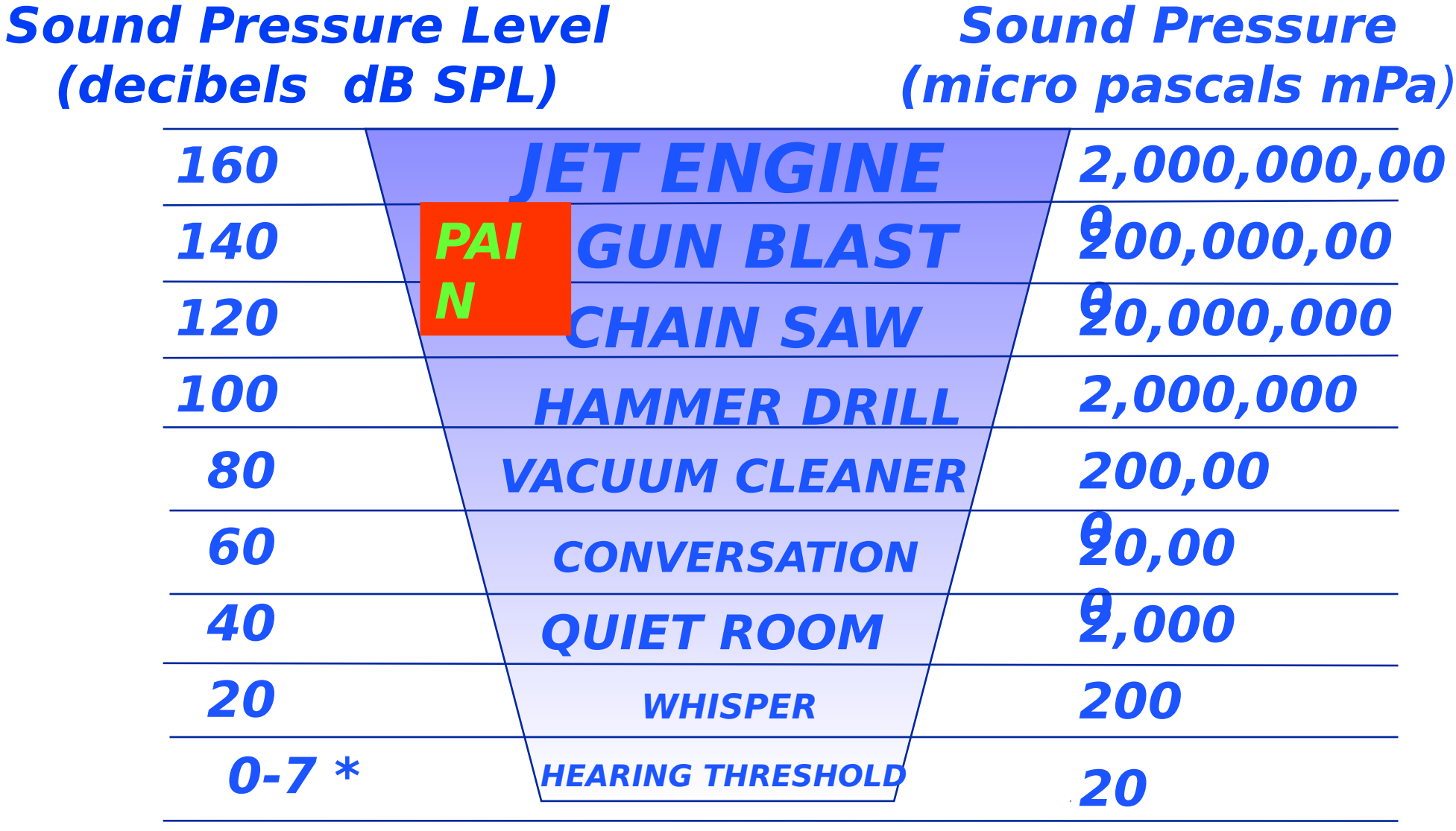
Human intensity range:

0 - 140+ dB SPL

a sound pressure range of 1:10,000,000 units

That's a ratio of 10 million to1!!!

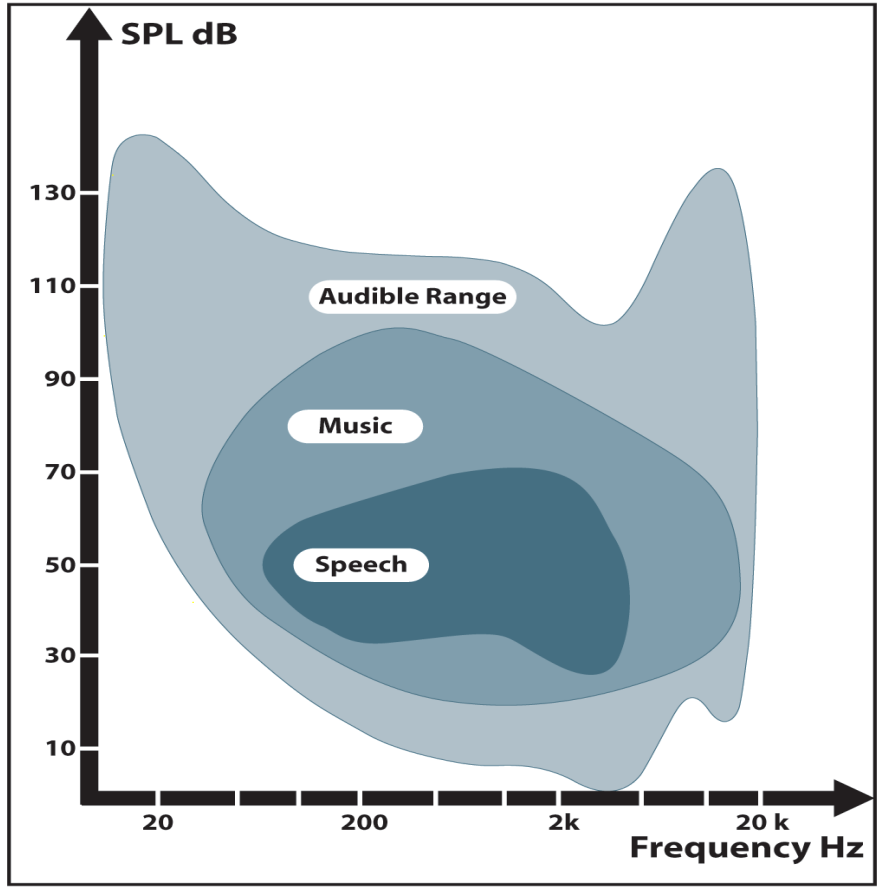
Sound Pressure Level SPL



* at 1000 Hz

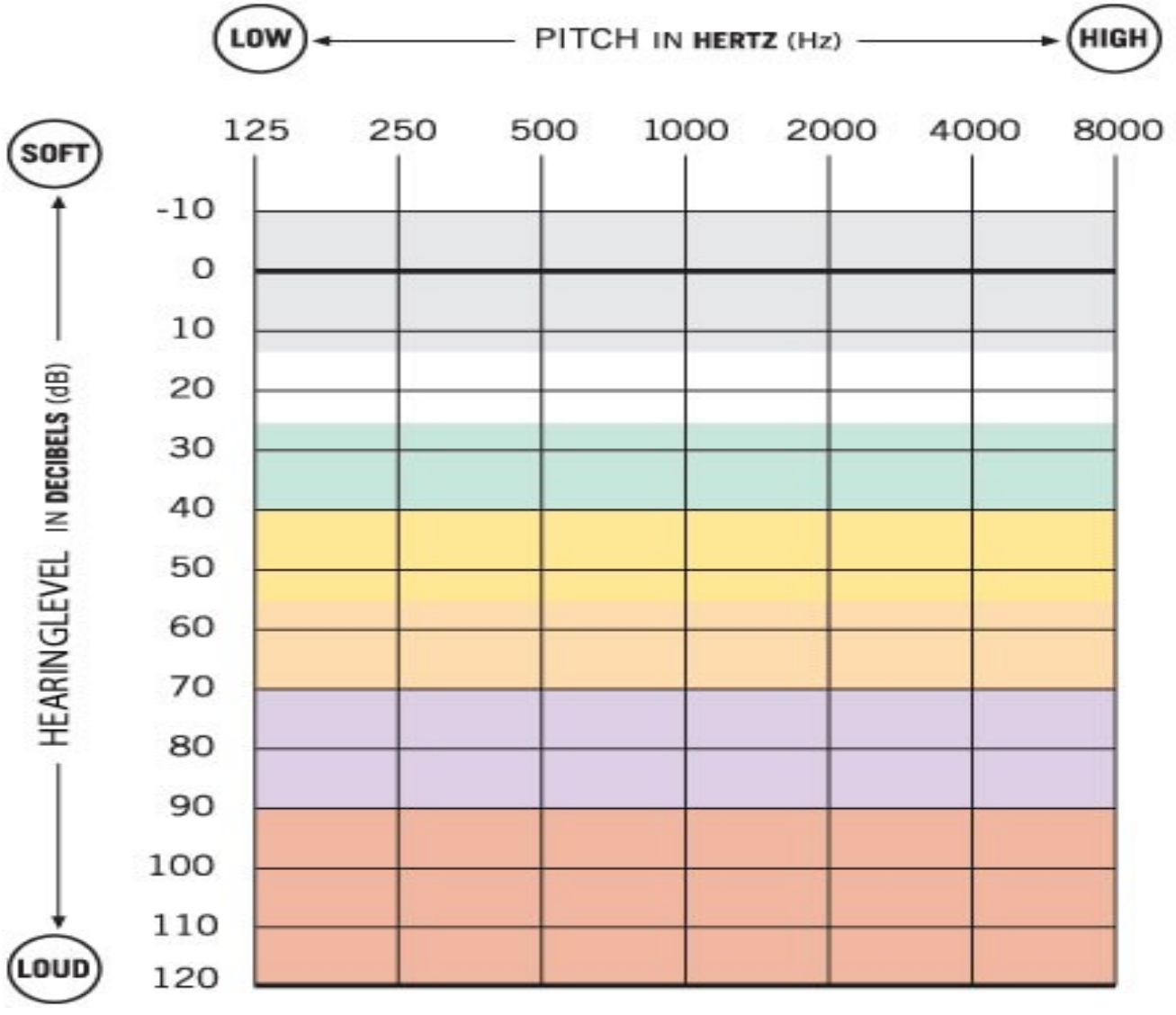
Hearing Level (HL)

- **Reference level based on young adults with healthy ears**
- **Our ears do not respond equally at all frequencies**
  0 dB HL ≠ 0 dB SPL
  varies by frequency
- **Audiogram is flipped so 0 dBHL is on top**



Yellow line = 0 dB HL

Audiogram


LOW
PITCH IN HERTZ (Hz)
HIGH
125
250
500
1000
2000
4000
8000
SOFT
HEARINGLEVEL IN DECIBELS (dB)
LOUD
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

Interaction of Intensity and Distance

93 dBA

88 dBA

82 dBA

10 m

20 m

76 dBA

40 m

Inverse Square Law

Doubling the distance from a sound source (in air) decreases intensity level by 6 dB*

applies in far field only, at several meters distance)

- **This principle is used to define noise hazard radius.**

More than One Sound Source #1

Sound Is NOT Additive!

93 dBA

93 dBA

96 dBA

- **Combining two different sound sources of equal loudness will increase overall intensity by 3 dB.**

More than One Sound Source #2

Sound Is NOT Additive!

93 dBA

95 dBA

97 dBA

Combined intensity of two sound sources of unequal loudness will vary with amount of dB difference

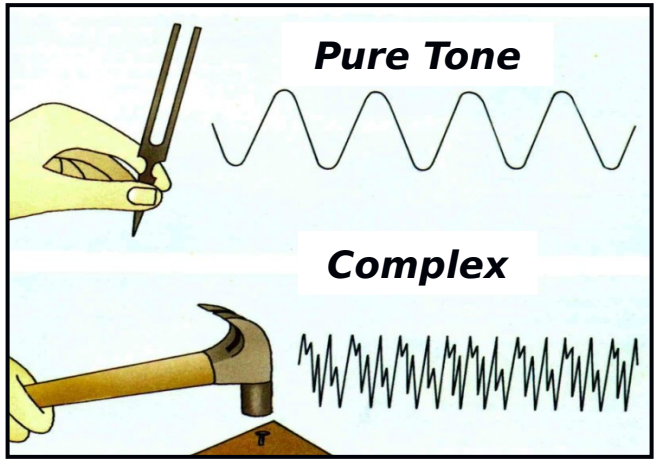
Difference in dB Values	Add to Higher Level
0-1 dB	3 dB
2-3 dB	2 dB
4-9 dB	1 dB
10 dB or more	0 dB

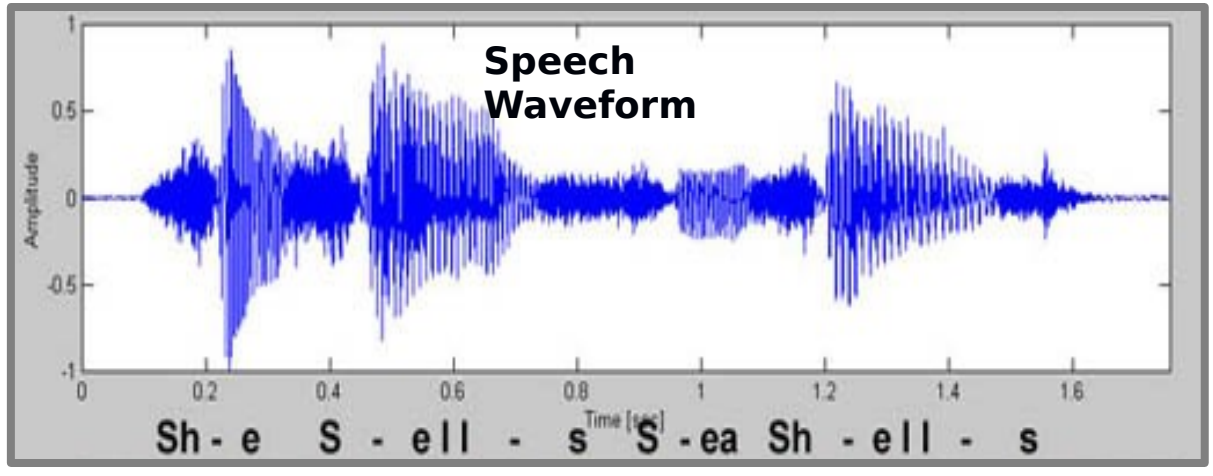
Duration

- **Perceived as Time**
- **Can range from thousandths of a second to several hours or all day**
- **Occupational noise can be a continuous (steady-state) or an impulse (impact) noise**
- **Consequences of exposures of hazardous noise levels vary with duration**

Spectrum

Combination of other three sound characteristics or parameters: frequency, intensity, and duration





Perceived as Quality of sound

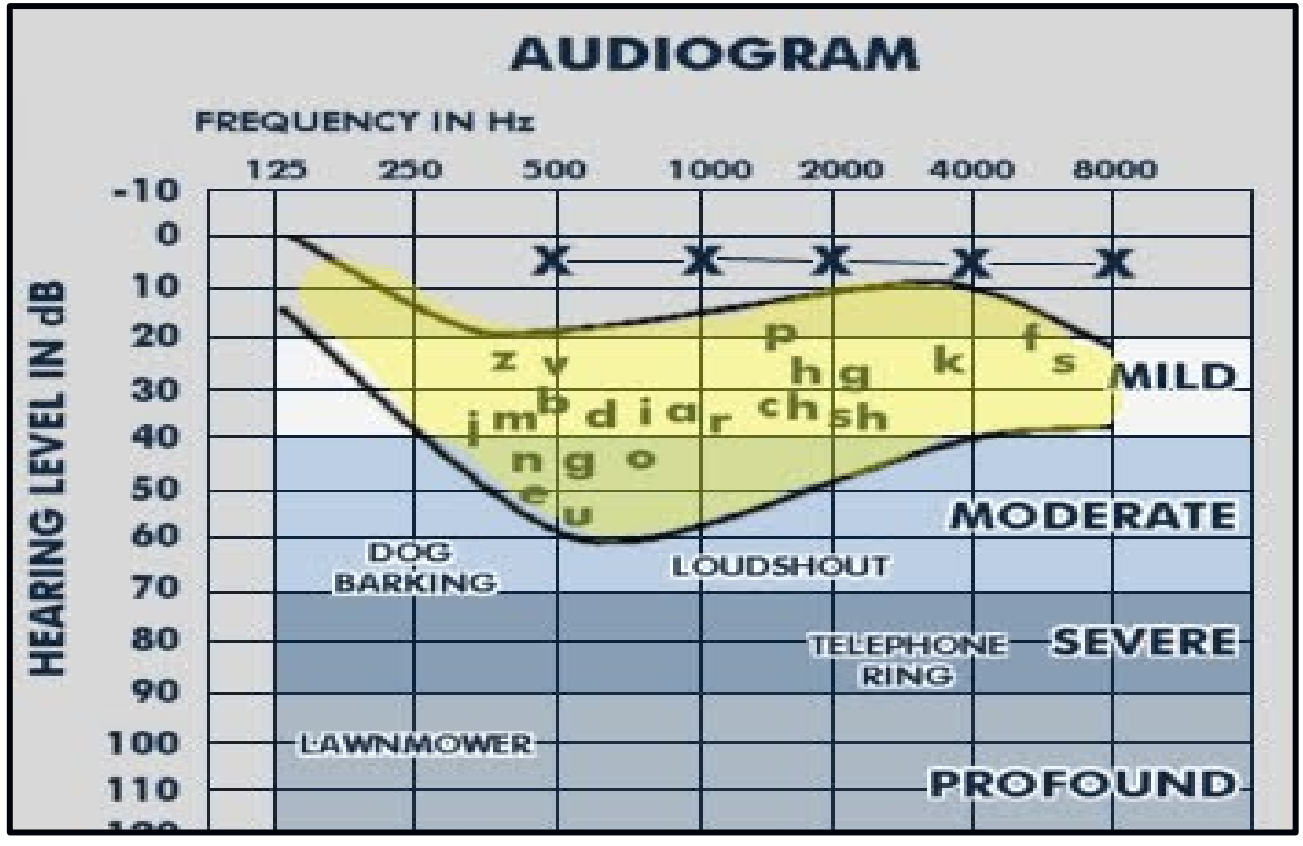
provides the identification of a sound source

Physics of Speech

Human speech is made of very complex sounds that rapidly occur in patterns that are meaningful to specific populations

VOWELS	**Louder** **High energy** **Low frequency** **80% of power of speech**
CONSONANTS	**Softer** **Low energy** **High frequency** **80% of understanding of speech**

“Speech Audiogram”



Questions?

Complex Wave Form via Laser Displayed Oscillos